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STATISTICAL ANALYSES OF METAL LEVELS IN FISH OF THE COLUMBIA RIVER NEAR THE INTERNATIONAL BOUNDARY, 1980 TO 1988

NORECOL ENVIRONMENTAL CONSULTANTS LTD.

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Inland Waters
Pacific and Yukon Region
Vancouver, B.C.

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ADDENDUM

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This report evaluates metal levels in Columbia River fish in relation to available (1988) Health and Welfare Canada guidelines for edible fish flesh. Subsequent to the release of this report the British Columbia Provincial government established a criteria for mercury and an alert level for total lead in fish tissue consumed by humans.

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1.0 INTRODUCTION

1.1 Background

From 1980 to 1983 Environment Canada and the British Columbia Ministry of Environment conducted a joint study of heavy metal levels in fish from the Columbia River upstream of the International Boundary. The study was initiated to address concerns that levels of mercury and other metals in fish tissues may be increasing because of discharges from Cominco's lead-zinc smelter at Trail or because of mobilization of biologically available metals from several reservoirs upstream.

Based on the results of the 1980 to 1983 study, an ongoing monitoring program was recommended (Smith 1987):

a) to provide data for comparison with Health and Welfare Canada Guidelines for edible fish flesh and

b) to monitor long-term trends in biologically available metals.

The recommended program included sampling and analyses for mercury, cadmium, chromium, copper, lead and zinc in largescale suckers (Catostomus macrocheilus), mountain whitefish (Prosopium williamsoni), and walleye

(Stizostedion vitreum), as well as white sturgeon (Acipenser transmontanus), if the latter could be obtained from local fishermen. Annual sampling (timed to correspond with the presence of walleye in the study area) was suggested for a three year period, after which sampling frequency could be reduced if metal levels were found to be stable or declining.

The program was implemented in 1986 and continued through 1988. Fish collected included the four recommended species plus rainbow trout (Oncorhynchus mykiss) formerly (S. gairdneri), although samples were obtained from only two sturgeon. Muscle tissue from all species collected was analyzed for mercury, and muscle tissue from all species except sturgeon was analyzed for cadmium, chromium, copper, lead, zinc and (in 1988 only) nickel.

1.2 Study Objectives

This report presents the results of the three years' monitoring and compares them with results from the 1980 to 1983 study. The objectives of this comparison are:

a) to evaluate metal levels in Columbia River fish in relation to Health and Welfare Canada guidelines for edible fish flesh,

b) to determine whether there have been significant changes in fish tissue metal concentrations between 1980 and 1988, with emphasis on identifying increases that would cause levels to exceed Health and Welfare guidelines, and

c) to determine whether annual monitoring should continue or monitoring frequency should be reduced.

The report is divided into four parts. In the first (Section 2.0), metal levels measured in all fish species are compared with current Health and Welfare Canada guidelines. In the second (Section 3.0), data for the entire study period (1980 to 1988) are examined for temporal trends. Conclusions are summarized in Section 4.0. Recommendations are presented in Section 5.0.

2.0 COMPARISON OF TISSUE METALS LEVELS WITH HEALTH AND WELFARE CANADA GUIDELINES

2.1 Statistical Tests

Descriptive statistics (mean, standard deviation and range) for each year were calculated for all metals except nickel and and all species except sturgeon. Data used in the analyses plus data not analyzed are presented in Appendix 2.1.

Data for fish collected from all locations between the International Boundary and the Hugh Keenleyside Dam were pooled for the calculations. Pooling of data from different locations is justified since the earlier study (Smith 1987) showed few differences among sites, and since the limited information about the movements of these species indicates that individuals may move throughout the study area.

Data from suckers obtained from Gifford Point in the Franklin D. Roosevelt Reservoir were not included in the analyses as these fish apparently represented a different population. Mercury levels in all individuals from the reservoir were greater than all but the highest concentration measured in a single sucker collected upstream of the border.

Means and ranges of mercury concentrations in all species were compared with existing Health and Welfare Canada guidelines for metals in edible fish flesh. When exceedances were noted for a species, the percentage of samples above the guideline was calculated.

2.2 Comparison of Mercury Levels with Guidelines

The Health Protection Branch of Health and Welfare Canada has established some guidelines for mercury in edible fish flesh. The primary guideline is 0.5 ug/g (wet weight) for persons consuming a typical Canadian diet containing fish. The Branch further recommends a limit of 0.2 ug/g (wet weight) for native populations who consume large quantities of fish (Wheatley 1979). There are no guidelines for other population subgroups who may consume atypical quantities of fish.

Mercury concentrations were well below the 0.5 ug/g guideline in all largescale suckers, mountain whitefish and rainbow trout sampled from 1986 to 1988 (Table 2.2-1). The maximum concentration found in these species was 0.39 ug/g measured in a largescale sucker. Average concentrations for all three species were less than 0.2 ug/g, but concentrations equal to or greater than this level were measured in 6 of the 46 suckers and 5 of the 44 whitefish collected during this period. During the entire study (1980 to 1988), mercury levels of 0.2 ug/g or greater were measured in 15% of the suckers and 13% of the whitefish. Rainbow trout were not found to exceed the 0.2 ug/g guideline.

Table 2.2-1

Concentrations of Mercury Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	0.16	0.13	-	0.15	0.18	0.15
S. D.	0.04	0.05	-	0.04	0.07	0.05
Minimum	0.09	<0.05	-	0.08	0.11	0.09
Maximum	0.22	0.22	-	0.24	0.39	0.26
Mountain Whitefish						
n	12	21	20	14	15	15
Mean	0.12	0.15	0.08	0.11	0.13	0.14
S. D.	0.05	0.06	0.07	0.04	0.07	0.04
Minimum	<0.05	<0.05	<0.05	<0.05	<0.05	0.09
Maximum	0.21	0.27	0.22	0.18	0.22	0.22
Walleye						
n	3	13	-	13	37	15
Mean	0.21	0.34	-	0.36	0.32	0.35
S. D.	0.05	0.10	-	0.18	0.16	0.14
Minimum	0.16	0.21	-	0.20	0.07	0.16
Maximum	0.25	0.55	-	0.76	1.02	0.68
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	0.04	-	0.04	0.08
S. D.	-	-	0.02	-	0.01	0.01
Minimum	-	-	<0.05	-	<0.05	0.07
Maximum	-	-	0.10	-	0.06	0.09

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Mercury concentrations were considerably higher in walleye than in the other fish species (Table 2.2-1). Mercury levels in eight individuals collected between 1986 and 1988 (12% of the sample) exceeded 0.5 ug/g, reaching a maximum concentration of 1.02 ug/g. In addition, 91% of all walleye sampled from 1986 to 1988 contained mercury levels equal to or greater than 0.2 ug/g. Considering that 65 walleye were sampled from 1986 to 1988 versus 16 sampled in 1980 and 1981, these proportions are not substantially different from the 6% of walleye with mercury levels above 0.5 ug/g and the 94% above 0.2 ug/g in the earlier study.

Since only two white sturgeon were obtained between 1986 and 1988, it is impossible to draw conclusions about mercury levels in this species. However, with a mercury content of 0.69 ug/g, one individual exceeded the guideline to protect typical consumers. The mercury concentration in the other individual was below the guideline at 0.16 ug/g. The mercury level in the single sturgeon collected in 1982 was 0.31 ug/g.

2.3 Comparison of Levels of Other Metals With Guidelines

At the present time there are no guidelines for metals other than mercury (Salminen 1988); rather all metals are assessed on the basis of a site specific evaluation. The Health Protection Branch carried out such an evaluation on the 1980 to 1983 data set (Salminen 1988) and concluded that, based on available fish consumption information, concentrations of the metals measured did not pose a health hazard.

Table 2.3-1

Concentrations of Cadmium Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	0.030	0.008	-	0.013	<0.02	0.011
S. D.	0.028	0.0053	-	0.0058	0	0.0026
Minimum	<0.010	<0.0085	-	<0.02	<0.02	<0.02
Maximum	0.11	0.020	-	0.030	<0.02	0.020
Mountain Whitefish						
n	11	21	13	14	15	15
Mean	0.019	0.012	0.023	0.021	0.015	0.020
S. D.	0.017	0.012	0.026	0.013	0.0092	0.014
Minimum	<0.011	<0.010	<.02	<0.02	<0.02	<0.02
Maximum	0.051	0.053	0.10	0.050	0.040	0.050
Walleye						
n	3	13	-	11	16	15
Mean	0.017	0.005	-	<0.02	<0.02	<0.02
S. D.	0.013	0.0014	-	0	0	0
Minimum	<0.010	<0.0092	-	<0.02	<0.02	<0.02
Maximum	0.030	0.010	-	<0.02	<0.02	<0.02
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	<0.02	-	<0.02	<0.02
S. D.	-	-	0	-	0	0
Minimum	-	-	<0.02	-	<0.02	<0.02
Maximum	-	-	<0.02	-	<0.02	<0.02

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Table 2.3-2

Concentrations of Chromium Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	0.36	0.21	-	<0.20	0.14	<0.20
S. D.	0.37	0.13	-	0	0.11	0
Minimum	<0.16	<0.13	-	<0.20	<0.20	<0.20
Maximum	1.6	0.59	-	<0.20	0.47	<0.20
Mountain Whitefish						
n	11	21	12	14	15	15
Mean	2.0	0.15	<0.20	0.11	0.13	<0.20
S. D.	2.8	0.089	0	0.045	0.073	0
Minimum	<0.17	<0.16	<0.20	<0.20	<0.20	<0.20
Maximum	9.5	0.33	<0.20	0.27	0.36	<0.20
Walleye						
n	3	13	-	11	16	15
Mean	0.44	0.19	-	<0.20	0.13	<0.20
S. D.	0.25	0.059	-	0	0.082	0
Minimum	0.25	<0.16	-	<0.20	<0.20	<0.20
Maximum	0.72	0.28	-	<0.20	0.36	<0.20
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	<0.20	-	0.13	<0.20
S. D.	-	-	0	-	0.058	0
Minimum	-	-	<0.20	-	<0.20	<0.20
Maximum	-	-	<0.20	-	0.28	<0.20

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Table 2.3-3

Concentrations of Copper Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	1.1	0.87	-	0.62	1.6	0.83
S. D.	0.91	0.30	-	0.13	0.75	0.31
Minimum	0.52	0.54	-	0.47	0.62	0.52
Maximum	4.5	1.6	-	0.97	3.3	1.8
Mountain Whitefish						
n	11	21	12	14	15	15
Mean	0.94	0.96	0.45	0.79	0.78	0.70
S. D.	0.28	0.39	0.15	0.57	0.21	0.18
Minimum	0.62	0.48	0.23	0.39	0.53	0.37
Maximum	1.6	2.3	0.66	2.5	1.3	0.98
Walleye						
n	3	13	-	11	16	15
Mean	0.69	0.91	-	0.26	0.59	0.42
S. D.	0.12	0.49	-	0.10	0.39	0.14
Minimum	0.56	0.40	-	0.10	0.23	0.10
Maximum	0.79	1.9	-	0.41	1.7	0.63
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	0.59	-	1.2	0.70
S. D.	-	-	0.17	-	0.57	0.16
Minimum	-	-	0.29	-	0.59	0.51
Maximum	-	-	0.82	-	2.0	0.82

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Table 2.3-4

Concentrations of Lead Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	0.49	0.31	-	0.60	0.83	0.51
S. D.	0.46	0.33	-	0.40	0.49	0.34
Minimum	0.042	0.052	-	<0.1	0.19	0.19
Maximum	1.6	1.2	-	1.7	1.7	1.5
Mountain Whitefish						
n	11	21	13	14	15	15
Mean	0.12	0.11	0.11	0.080	0.090	0.080
S. D.	0.12	0.12	0.086	0.067	0.045	0.045
Minimum	<0.014	<0.013	<0.1	<0.1	<0.1	<0.1
Maximum	0.36	0.53	0.30	0.29	0.18	0.17
Walleye						
n	3	13	-	11	16	15
Mean	0.026	0.032	-	<0.1	<0.1	0.070
S. D.	0.034	0.015	-	0	0	0.096
Minimum	<0.010	0.010	-	<0.1	<0.1	<0.1
Maximum	0.065	0.060	-	<0.1	<0.1	0.42
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	0.10	-	<0.1	<0.1
S. D.	-	-	0	-	0	0
Minimum	-	-	<0.1	-	<0.1	<0.1
Maximum	-	-	0.20	-	<0.1	<0.1

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Table 2.3-5

Concentrations of Zinc Measured in Muscle Tissue of Fish Collected from the Columbia River from 1980 to 1988[a]

SPECIES STATISTIC	1980	1981	1983	1986	1987	1988
Largescale sucker						
n	18	15	-	16	15	15
Mean	8.2	8.4	-	8.8	8.4	6.8
S. D.	2.5	2.6	-	1.9	1.7	1.7
Minimum	5.3	5.2	-	6.0	5.6	4.1
Maximum	15	15	-	13	12	10
Mountain Whitefish						
n	11	21	13	14	15	15
Mean	4.9	4.8	5.8	7.9	5.7	4.6
S. D.	0.94	0.77	1.2	8.5	1.2	0.76
Minimum	4.0	3.6	3.6	3.3	4.2	3.5
Maximum	6.5	6.2	8.0	37	8.3	5.8
Walleye						
n	3	13	-	11	16	15
Mean	4.6	5.0	-	4.6	5.5	4.8
S. D.	0.17	0.77	-	0.77	0.58	0.72
Minimum	4.5	4.0	-	3.8	4.7	3.5
Maximum	4.8	6.3	-	6.2	6.4	5.9
Rainbow Trout						
n	-	-	15	-	7	3
Mean	-	-	6.3	-	6.4	3.6
S. D.	-	-	1.7	-	0.61	0.53
Minimum	-	-	3.6	-	5.5	3.2
Maximum	-	-	9.7	-	7.3	4.2

[a] Values reported as ug/g wet weight.

Note: When values less than the detection limit were obtained, a value of one half the detection limit was used in the statistical calculations.

Levels of cadmium, chromium, copper, lead and zinc in fish collected from 1986 to 1988 were not substantially different from levels measured previously (Tables 2.3-1 to 2.3-5 and Section 3.3). Therefore, evaluation of these data by the Health Protection Branch is considered to be unnecessary.

3.0 COMPARISON OF METAL LEVELS AMONG YEARS

3.1 Statistical Tests

Differences in metal levels among years were assessed using a Lotus 123 spreadsheet which calculates one-way analysis of variance and covariance and performs a Bartlett's test for homogeneity of variances. The tests for main (treatment) effects were performed on metal concentrations. Fish length was the covariate. Concentrations of metals below detection limits were set at half the detection limit for these tests. Separate tests were performed for each metal in each species.

Both analysis of variance and analysis of covariance assume that the variances of the groups being tested are equal. In order to ensure homogeneity of variances (if possible), the Bartlett's test and data transformation were employed. First, the spreadsheet was run using untransformed data. If the Bartlett's test showed significant heterogeneity, the analysis was repeated using ln-transformed data. When transformation reduced or eliminated the heteroscedasticity, the transformed data were used for further tests; otherwise the untransformed data were used.

In a few cases, even with transformations it was not possible to achieve homogeneity of variances. This violation of one of the assumptions of the analyses is not a problem, since moderate heteroscedasticity does

not seriously bias the F-test for main effects (Sokal and Rohlf 1981). However, it can bias many of the *a posteriori* tests for differences among pairs of means, and therefore affects the choice of a multiple range test.

Initially, differences among years were evaluated using the F-test from the analysis of variance or the analysis of covariance. The more appropriate of these analyses was determined by the covariance test for significance of the pooled regression coefficient. For data sets in which the regression was significant, the covariance analysis was used to assess differences among years. When the regression coefficient was not significant, the analysis of variance was used.

When the F-test for differences among years was significant, multiple range tests were used to evaluate differences among all possible pairs of means. For data sets having equal variances, the Tukey-Kramer test, which is appropriate for use with an analysis of variance having unequal group sizes (Sokal and Rohlf 1981), was employed. For analyses of variance in which significant heteroscedasticity remained even after transformation, the Games and Howell test, which assumes unequal variances (Sokal and Rohlf 1981), was used. No multiple range test which assumes unequal group variances was found to be appropriate for comparing adjusted group means from the analysis of covariance.

The statistical tests performed for each metal in each fish species are summarized in Table 3.1-1.

TABLE 3.3-1

SIGNIFICANCE OF F-TESTS FROM ANALYSES OF VARIANCE/COVARIANCE FOR AMONG-YEAR DIFFERENCES IN METAL CONCENTRATIONS IN FISH OF THE COLUMBIA RIVER

METAL	LARGESCALE SUCKERS	MOUNTAIN WHITEFISH	WALLEYE	RAINBOW TROUT
Mercury	not significant	not significant	not significant	not significant
Cadmium	significant only with 1980-81 data[b]	not significant	not tested[a]	not tested[a]
Chromium	significant only with 1980-81 data[b]	significant only with 1980-81 data[b]	significant only with 1980-81 data[b]	not tested[a]
Copper	significant ($P < 0.01$)	significant ($P < 0.01$)	significant ($P < 0.01$)	significant ($P < 0.01$)
Lead	significant only with 1980-81 data	not significant	not significant[b]	not tested[a]
Zinc	significant only without 1980-81 data	significant ($P < 0.05$)	significant ($P < 0.05$)	significant ($P < 0.05$)

a Statistical tests not performed because metal not detectable in species indicated.

b Results suspect due to zero variance in some cells (metal undetectable in all samples from one or more years)

Two sets of analyses, one including and one excluding the 1980 and 1981 data, were performed for all metals except mercury. In 1980 and 1981, the chemical assays for metals other than mercury had been performed by different techniques than those used from 1983 to 1988. Therefore, data from the first two years were not truly comparable with the remainder of the data set. The two statistical analyses partially distinguished between actual differences among years and differences in analytical techniques.

3.2 Comparison of Mercury Levels Among Years

No significant differences in mercury levels among years were found for any of the four fish species (Table 2.2-1 and Appendix 3.2). Therefore, mercury levels in fish from the study area appear stable.

3.3 Comparison of Levels of Other Metals Among Years

Results of the analyses of variance or covariance are summarized in Table 3.3-1. Complete results are presented in Appendix 3.3.

Significant differences in levels of cadmium, chromium and lead occurred only when the 1980 and 1981 data were included. This result implies that the differences were due to the changes in analytical techniques, which is not surprising since the two techniques employed different detections limits. It is conceivable that real differences in tissue metal levels also occurred, but it is not possible to separate real differences from analytical differences. Statistical tests on the

TABLE 3.1-1

SUMMARY OF STATISTICAL TESTS USED TO DESCRIBE AMONG-YEAR VARIATION IN TISSUE METAL LEVELS IN FISH FROM THE COLUMBIA RIVER

METAL	LARGESCALE SUCKERS	MOUNTAIN WHITEFISH	WALLEYE	RAINBOW TROUT
Mercury	COVAR[a] no transformation	COVAR no transformation	COVAR no transformation	COVAR no transformation
Cadmium	ANOVA no transformation	ANOVA no transformation	not tested	not tested
Chromium	ANOVA no transformation	ANOVA no transformation	ANOVA no transformation	not tested
Copper	ANOVA ln-transformation[b] Range: GH	ANOVA ln-transformation Range: GH, TK	ANOVA ln-transformation Range: TK	ANOVA ln-transformation Range: TK
Lead	ANOVA no transformation	ANOVA no transformation	ANOVA no transformation	not tested
Zinc	ANOVA no transformation Range: TK	COVAR ln-transformation Range: none appropriate	ANOVA no transformation Range: TK	COVAR ln-transformation Range: none appropriate

ANOVA - Analysis of variance
COVAR - Analysis of covariance
GH - Games and Howell Multiple Range Test for unequal variances
TK - Tukey-Kramer Multiple Range Test for equal variances, unequal sample sizes

a

b ANCOVA used only if the F-test for the pooled regression coefficient was significant ($P<0.05$). ln-transformation used only if Bartlett's test showed significant heteroscedasticity and if transformation improved heteroscedasticity.

1983 to 1988 data show that levels of cadmium, chromium and lead in all four species were stable during this period.

Analyses of variance or covariance showed significant annual variations in copper and zinc concentrations in all four species. Significant differences among pairs of years, as identified by multiple range tests, are summarized in Table 3.3-2. Although copper and zinc levels varied from year to year, these tests suggest no clear trends.

To identify patterns of variability, mean copper and zinc concentrations in each species for 1986, 1987 and 1988 were plotted (Figures 3.3-1 and 3.3-2). These graphs show similar patterns of variability from year to year in most species. The highest copper concentrations in all species were recorded in 1987. The lowest zinc concentrations in all species except walleye were recorded in 1988.

To evaluate these findings fully it is necessary to determine whether differences in fish tissue metal levels are related to similar differences in environmental levels. Zinc loadings in the effluents from the Cominco complex declined steadily between 1977 and 1984 (Smith 1987) and decreased even more rapidly from 1986 to 1988 (Sheehan, personal communication). Thus, the apparent reduction in zinc levels in large scale suckers, mountain whitefish and rainbow trout (Figure 3.3.-2) may be related to decreased environmental levels.

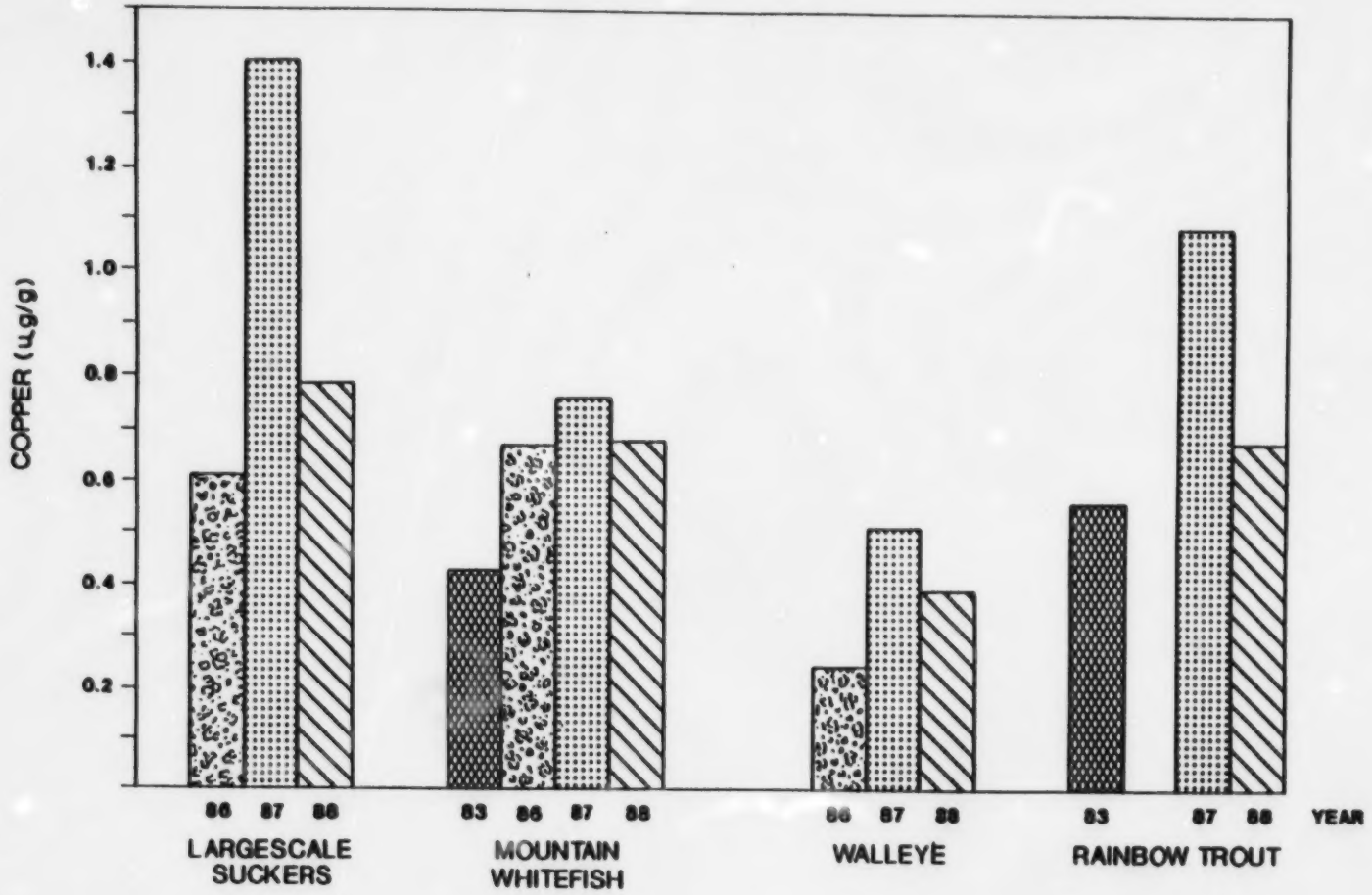
TABLE 3.3-2

SIGNIFICANT (P <0.05) AMONG-YEAR DIFFERENCES IN COPPER AND ZINC CONCENTRATIONS IN FISH OF THE COLUMBIA RIVER, AS INDICATED BY MULTIPLE RANGE TESTS[a]

SPECIES	COPPER	ZINC
Largescale Suckers	1987>1988 1987>1986	1986>1988
Mountain Whitefish	1980>1983 1981>1983 1987>1983 1986>1983 1988>1983	no appropriate test
Walleye	1981>1988 1981>1986 1980>1986 1987>1986 1988>1986[b]	1987>1988 1987>1986
Rainbow Trout	1987>1983	no appropriate test

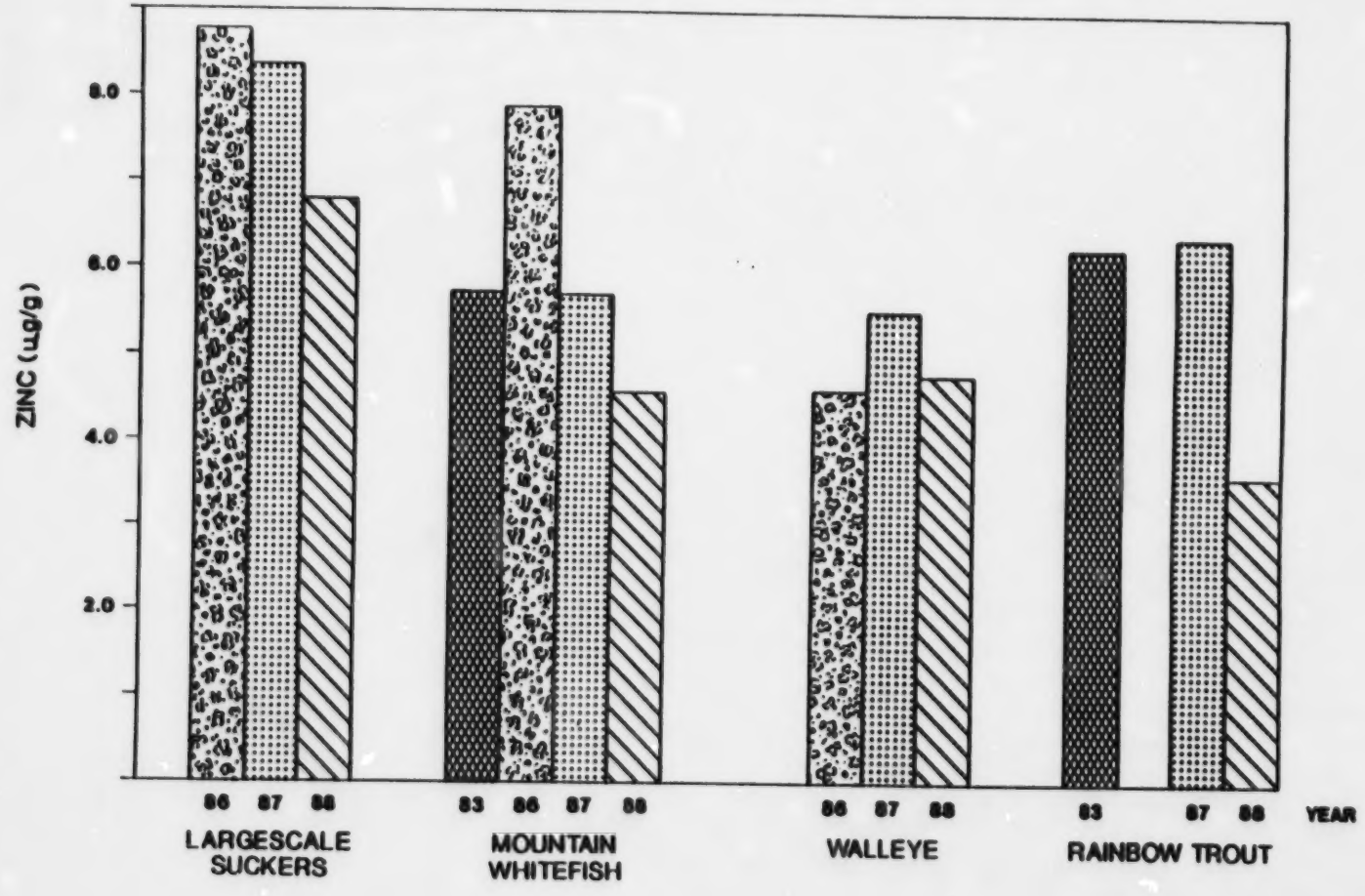
a Differences between any pairs of means not listed were not significant.

b Significant only when 1980 and 1981 data not included



MEAN COPPER LEVELS IN FISH 1983-1988

Figure no. 3.3-1	COLUMBIA RIVER PROJECT
Date Mar. 1989	Drawn by NORECOL



MEAN ZINC LEVELS IN FISH 1983-1988

Figure no. 3.3-2	COLUMBIA RIVER PROJECT
Date Mar. 1989	Drawn by NORECOL

4.0 CONCLUSIONS

4.1 Comparison of Tissue Metal Levels with Health and Welfare Canada Guidelines

a) Mercury concentrations in 11% of the walleye collected from 1980 to 1988 exceeded the Health Protection Branch guideline (0.5 ug/g) for typical Canadian consumers. Mercury levels in largescale suckers, mountain whitefish, and rainbow trout were well below this guideline.

b) There are no established guidelines for metals other than mercury in edible fish tissues, but the Health Protection Branch does site specific assessments of other metals. Levels of cadmium, chromium, copper, lead and zinc measured from 1986 to 1988 did not differ significantly from the 1980 to 1983 concentrations of these metals which were assessed by the Health Protection Branch and deemed not hazardous.

4.2 Comparison of Metal Levels Among Years

a) Mercury levels in largescale suckers, mountain whitefish, walleye and rainbow trout collected from 1980 to 1988 did not differ significantly among years.

b) Cadmium, chromium and lead levels were stable from 1983 to 1988. Differences in levels of these metals between 1980 to 1981 and 1983 to 1988 were most likely due to differences in analytical techniques. Real differences in tissue metal levels, if any, could not be distinguished from differences due to analytical methods.

c) Among-year differences in copper and zinc were significant in all four species but showed no overall upward or downward trend. Maximum copper levels in all species were recorded in 1987. Minimum zinc levels in all species except walleye were recorded in 1988.

d) There is no evidence that metal levels in Columbia River fish are either increasing or decreasing.

5.0 RECOMMENDATIONS

a) Since the data indicate that metal levels in Columbia River fish remained stable from 1980 to 1988, monitoring frequency can be reduced. A sampling interval of three to five years would be appropriate, unless concerns arise from changes in water use such as new or expanding industries discharging additional effluents containing metals.

b) Mercury levels in walleye should be monitored somewhat more frequently, if a significant sports fishery for this species continues. A sampling interval of no more than three years is suggested.

c) If a significant sports fishery for sturgeon exists, additional information on mercury levels in the species is required. Only three sturgeon have been sampled since 1980, and one of these had a mercury concentration above the 0.5 ug/g Health Protection Branch guideline. A better estimate of the proportion of the population exceeding the guideline is needed.

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APPENDIX 2-1

SAMPLING INFORMATION AND TISSUE METAL DATA FOR FISH COLLECTED FROM THE COLUMBIA RIVER BETWEEN THE HUGH KEENLEYSIDE DAM AND THE INTERNATIONAL BOUNDARY 1986 TO 1988

(Pages 1 to 6)

APPENDIX 2-1

TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
Largescale suckers					
0015	July 7, 1986	Beaver Creek to Waneta	1135	46.5	6
0013	July 7, 1986	Beaver Creek to Waneta	1050	48	6
0014	July 7, 1986	Beaver Creek to Waneta	1800	54	9
0011	July 7, 1986	Beaver Creek to Waneta	1400	50	-
0012	July 7, 1986	Beaver Creek to Waneta	1250	48.5	8
-	July 8, 1986	Trail to Rock Island	1450	50.5	8
0016	July 8, 1986	Trail to Rock Island	1790	50	6
-	July 8, 1986	Trail to Rock Island	1150	43	4
-	July 8, 1986	Trail to Rock Island	1000	42.5	5
0625	July 8, 1986	Trail to Rock Island	1240	47	7
-	July 8, 1986	Trail to Rock Island	1290	47.5	-
-	July 8, 1986	Trail to Rock Island	1240	47.5	7
-	July 8, 1986	Trail to Rock Island	1420	51	5
0611	July 8, 1986	Trail to Rock Island	1650	50.5	7
0654	July 8, 1986	Trail to Rock Island	900	44.5	5
-	July 8, 1986	Trail to Rock Island	1690	49.5	8
-	July 8, 1986	Trail to Rock Island	1300	49	-
0655	July 8, 1986	Trail to Rock Island	1040	42.5	6
0653	July 8, 1986	Trail to Rock Island	1010	42.5	-
0017	July 8, 1986	Trail to Rock Island	1060	45.5	5
0621	July 8, 1986	Trail to Rock Island	1440	47	6
0623	July 8, 1986	Trail to Rock Island	950	41	5
-	July 8, 1986	Trail to Rock Island	1110	46.5	6
0610	July 8, 1986	Trail to Rock Island	1010	44	10
0624	July 8, 1986	Trail to Rock Island	940	43.5	6
-	July 8, 1986	Trail to Rock Island	1250	44	8
0004	Sept. 23, 1986	Gifford Point, USA	-	47.2	-
0003	Sept. 23, 1986	Gifford Point, USA	-	45.3	-
0002	Sept. 23, 1986	Gifford Point, USA	-	49.1	-
0006	Sept. 23, 1986	Gifford Point, USA	-	44.5	-
0005	Sept. 23, 1986	Gifford Point, USA	-	47	-
0001	Sept. 23, 1986	Gifford Point, USA	-	49.5	-
0007	Sept. 23, 1986	Gifford Point, USA	-	47.3	-

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TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
1511	July 14, 1987	Beaver Creek to Waneta	1432	49	8
1502	July 14, 1987	Beaver Creek to Waneta	1030	47.5	-
1513	July 14, 1987	Beaver Creek to Waneta	1650	51	7
1505	July 14, 1987	Beaver Creek to Waneta	1003	47	7
1501	July 14, 1987	Beaver Creek to Waneta	1240	49	8
1504	July 14, 1987	Beaver Creek to Waneta	1425	51	10
1514	July 14, 1987	Beaver Creek to Waneta	1480	51	10
1503	July 14, 1987	Beaver Creek to Waneta	1362	49.5	9
1509	July 14, 1987	Beaver Creek to Waneta	1430	48	7
1506	July 14, 1987	Beaver Creek to Waneta	1210	47	8
1507	July 14, 1987	Beaver Creek to Waneta	1480	50.5	9
1510	July 14, 1987	Beaver Creek to Waneta	1080	45	7
1512	July 14, 1987	Beaver Creek to Waneta	1360	50.5	12
1508	July 14, 1987	Beaver Creek to Waneta	1180	47	8
1500	July 14, 1987	Beaver Creek to Waneta	1160	49	10
0011	July 4, 1988	Beaver Creek to Waneta	1394	49	8
0000	July 4, 1988	Beaver Creek to Waneta	1229	46.7	14
0003	July 4, 1988	Beaver Creek to Waneta	1043	43.8	7
0006	July 4, 1988	Beaver Creek to Waneta	882	42	7
0008	July 4, 1988	Beaver Creek to Waneta	1190	48.4	12
0014	July 4, 1988	Beaver Creek to Waneta	896	43.1	7
0012	July 4, 1988	Beaver Creek to Waneta	1496	51.7	12
0013	July 4, 1988	Beaver Creek to Waneta	1512	51.3	10
0009	July 4, 1988	Beaver Creek to Waneta	1046	46.3	12
0010	July 4, 1988	Beaver Creek to Waneta	1462	49	10
0002	July 4, 1988	Beaver Creek to Waneta	1013	43.6	11
0004	July 4, 1988	Beaver Creek to Waneta	1613	49	10
0001	July 4, 1988	Beaver Creek to Waneta	959	46	8
0005	July 4, 1988	Beaver Creek to Waneta	1495	50.3	11
0007	July 4, 1988	Beaver Creek to Waneta	1071	45.2	10
Mountain whitefish					
0018	July 7, 1986	Beaver Creek to Waneta	470	37	4
0608	July 7, 1986	Beaver Creek to Waneta	400	34	6
0604	July 7, 1986	Beaver Creek to Waneta	500	30	4

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TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
0603	July 7, 1986	Beaver Creek to Waneta	560	38	6
0600	July 7, 1986	Beaver Creek to Waneta	690	37	5
0602	July 7, 1986	Beaver Creek to Waneta	680	35.5	5
0020	July 7, 1986	Beaver Creek to Waneta	450	35	5
0019	July 7, 1986	Beaver Creek to Waneta	710	35.5	5
0601	July 7, 1986	Beaver Creek to Waneta	490	35	5
0609	July 7, 1986	Beaver Creek to Waneta	2300	48.5	7
0606	July 7, 1986	Beaver Creek to Waneta	450	32.5	5
0605	July 7, 1986	Beaver Creek to Waneta	750	36.5	5
0607	July 7, 1986	Beaver Creek to Waneta	650	40	7
0656	July 8, 1986	Trail to Rock Island	500	35	5
6843	July 13, 1987	Beaver Creek to Waneta	200	27	3
6845	July 13, 1987	Beaver Creek to Waneta	400	36.6	6
6846	July 13, 1987	Beaver Creek to Waneta	300	34	5
6827	July 13, 1987	Beaver Creek to Waneta	710	39.5	5
6840	July 13, 1987	Beaver Creek to Waneta	300	30.8	4
6828	July 13, 1987	Beaver Creek to Waneta	622	34	5
6832	July 13, 1987	Beaver Creek to Waneta	770	40	5
6838	July 13, 1987	Beaver Creek to Waneta	400	36.5	7
6830	July 13, 1987	Beaver Creek to Waneta	630	38.5	5
6844	July 13, 1987	Beaver Creek to Waneta	500	34.5	5
6834	July 13, 1987	Beaver Creek to Waneta	612	37.5	6
6831	July 13, 1987	Beaver Creek to Waneta	1080	48.5	8
6829	July 13, 1987	Beaver Creek to Waneta	540	38	6
6833	July 13, 1987	Beaver Creek to Waneta	540	37	5
6841	July 13, 1987	Beaver Creek to Waneta	150	25.4	3
0017	July 4, 1988	Beaver Creek to Waneta	638	38.5	5
0018	July 4, 1988	Beaver Creek to Waneta	467	37.3	5
0019	July 4, 1988	Beaver Creek to Waneta	531	35.7	5
0026	July 5, 1988	Trail to Rock Island	913	41.9	7
0031	July 5, 1988	Trail to Rock Island	499	35.9	5
0023	July 5, 1988	Trail to Rock Island	787	39.3	5
0034	July 5, 1988	Trail to Rock Island	610	37.9	6
0028	July 5, 1988	Trail to Rock Island	600	38.5	4
0025	July 5, 1988	Trail to Rock Island	449	34.8	4

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TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
0029	July 5, 1988	Trail to Rock Island	557	34.8	4
0033	July 5, 1988	Trail to Rock Island	406	36.5	5
0030	July 5, 1988	Trail to Rock Island	451	37	4
0027	July 5, 1988	Trail to Rock Island	458	35.7	5
0032	July 5, 1988	Trail to Rock Island	549	34.3	5
0024	July 5, 1988	Trail to Rock Island	633	39.5	6
Rainbow trout					
6847	July 13, 1987	Beaver Creek to Waneta	1500	50	3
6849	July 13, 1987	Beaver Creek to Waneta	900	42	3
6837	July 13, 1987	Beaver Creek to Waneta	1200	43.5	-
6848	July 13, 1987	Beaver Creek to Waneta	1200	53	3
6836	July 13, 1987	Beaver Creek to Waneta	1000	41.5	4
6835	July 13, 1987	Beaver Creek to Waneta	1000	39.4	4
6826	July 13, 1987	Beaver Creek to Waneta	260	26.5	3
0015	July 4, 1988	Beaver Creek to Waneta	1695	52.5	3
0022	July 4, 1988	Beaver Creek to Waneta	1466	50.5	3
0016	July 4, 1988	Beaver Creek to Waneta	1218	48	3
Sturgeon					
-	July 13, 1986	Beaver Creek to Waneta	-	-	-
-	April 11, 1987	Beaver Creek to Waneta	36200	178	-
Walleye					
0003	July 7, 1986	Beaver Creek to Waneta	750	41	3
0004	July 7, 1986	Beaver Creek to Waneta	980	43.5	5
0006	July 7, 1986	Beaver Creek to Waneta	750	43	4
0000	July 7, 1986	Beaver Creek to Waneta	1050	46.5	4
0005	July 7, 1986	Beaver Creek to Waneta	990	47	4
0009	July 7, 1986	Beaver Creek to Waneta	400	36	3
0001	July 7, 1986	Beaver Creek to Waneta	500	36.5	3
0007	July 7, 1986	Beaver Creek to Waneta	570	38	3
0008	July 7, 1986	Beaver Creek to Waneta	1030	44.5	4
0010	July 7, 1986	Beaver Creek to Waneta	435	34.5	2
0002	July 7, 1986	Beaver Creek to Waneta	430	36	3

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TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
0001	Aug. 12, 1986	Hugh Keenleyside Dam	-	-	-
0002	Aug. 12, 1986	Hugh Keenleyside Dam	-	-	-
6839	July 13, 1987	Beaver Creek to Waneta	400	35.2	3
6842	July 13, 1987	Beaver Creek to Waneta	200	34.3	2
6635	July 13, 1987	Beaver Creek to Waneta	500	35.5	3
6638	July 13, 1987	Beaver Creek to Waneta	230	28.5	2
6633	July 13, 1987	Beaver Creek to Waneta	440	37	3
6639	July 13, 1987	Beaver Creek to Waneta	290	31	2
6631	July 13, 1987	Beaver Creek to Waneta	470	37	3
6626	July 13, 1987	Beaver Creek to Waneta	310	34	3
6629	July 13, 1987	Beaver Creek to Waneta	270	33	3
6627	July 13, 1987	Beaver Creek to Waneta	410	33.5	2
6628	July 13, 1987	Beaver Creek to Waneta	470	37	3
6632	July 13, 1987	Beaver Creek to Waneta	350	34	2
6636	July 13, 1987	Beaver Creek to Waneta	340	32.5	2
6634	July 13, 1987	Beaver Creek to Waneta	390	35	2
6630	July 13, 1987	Beaver Creek to Waneta	360	33	2
6637	July 13, 1987	Beaver Creek to Waneta	230	27.5	2
-	July 26, 1987	Hugh Keenleyside Dam	985	45	7
-	Aug. 20, 1987	Hugh Keenleyside Dam	801	43.5	6
-	Aug. 21, 1987	Hugh Keenleyside Dam	921	44	7
-	Aug. 24, 1987	Castlegar	859	41	5
-	Aug. 24, 1987	Castlegar	607	39	4
-	Aug. 24, 1987	Castlegar	854	43.5	5
-	Aug. 26, 1987	Beaver Creek to Waneta	800	43	6
-	Aug. 27, 1987	Beaver Creek to Waneta	576	39	4
-	Sept. 10,1987	Beaver Creek to Waneta	1788	53	8
-	Sept. 10,1987	Hugh Keenleyside Dam	1160	47	7
-	Sept. 11, 1987	Hugh Keenleyside Dam	845	44	4
-	Sept. 13, 1987	Beaver Creek to Waneta	602	48	6
-	Sept. 13, 1987	Hugh Keenleyside Dam	1192	48.5	6
-	Sept. 13, 1987	Hugh Keenleyside Dam	1825	54	7
-	Sept. 15, 1987	Castlegar	851	46	5
-	Sept. 20, 1987	Hugh Keenleyside Dam	779	42	5
-	Sept. 20, 1987	Hugh Keenleyside Dam	706	41	6

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TABLE 1

Sampling Information and Some Biological Characteristics of Fish Collected from the Columbia River from 1986 to 1988

SAMPLE NUMBER	DATE COLLECTED	COLLECTION SITE	WEIGHT (g)	LENGTH (cm)	AGE (years)
-	Sept. 24, 1987	Castlegar	2031	55.4	8
-	Sept. 29, 1987	Castlegar	2867	59	9
-	Oct 4,1987	Genelle	831	42.5	5
-	Oct 8,1987	Castlegar	2341	56	8
0021	July 4, 1988	Beaver Creek to Waneta	633	43	5
0020	July 4, 1988	Beaver Creek to Waneta	578	38.8	4
0047	July 5, 1988	Castlegar	362	37.4	3
0038	July 5, 1988	Castlegar	740	41.5	3
0039	July 5, 1988	Castlegar	759	43.5	4
0042	July 5, 1988	Castlegar	518	37.5	4
0036	July 5, 1988	Castlegar	1248	50.3	3
0040	July 5, 1988	Castlegar	734	42.5	4
0041	July 5, 1988	Castlegar	665	40.4	3
0043	July 5, 1988	Castlegar	629	39.5	3
0045	July 5, 1988	Castlegar	476	35.5	4
0044	July 5, 1988	Castlegar	582	39.7	4
0037	July 5, 1988	Castlegar	582	37.4	4
0046	July 5, 1988	Castlegar	511	37	3
0035	July 5, 1988	Trail to Rock Island	1282	52.1	4

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TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	Largescale suckers								
	0015	0.14	0.16	<0.02	<0.2	0.52	-	0.18	9.2
	0013	0.19	0.18	0.03	<0.2	0.51	-	0.90	12.
	0014	0.15	0.20	<0.02	<0.2	0.59	-	0.44	6.8
	0011	0.13	0.14	<0.02	<0.2	0.54	-	0.84	9.7
	0012	0.10	0.10	<0.02	<0.2	0.57	-	0.85	7.0
	0016	0.15	0.18	0.02	<0.2	0.64	-	0.73	11.
	0625	0.10	0.11	<0.02	<0.2	0.62	-	0.34	8.1
1986	0611	0.17	0.17	<0.02	<0.2	0.57	-	<0.1	6.0
	0654	0.15	0.15	<0.02	<0.2	0.97	-	1.7	13.
	0655	0.08	0.08	<0.02	<0.2	0.67	-	0.33	8.5
	0653	0.24	0.21	<0.02	<0.2	0.74	-	0.37	8.0
	0017	0.14	0.15	<0.02	<0.2	0.71	-	0.17	8.8
	0621	0.15	0.15	<0.02	<0.2	0.52	-	0.35	7.6
	0623	0.14	0.15	<0.02	<0.2	0.81	-	0.75	6.9
	0610	0.14	0.18	<0.02	<0.2	0.48	-	0.79	8.7
	0624	0.16	0.14	<0.02	<0.2	0.47	-	0.81	9.4
	0004	0.49	-	-	-	-	-	-	-
	0003	0.49	-	-	-	-	-	-	-
U.S.	0002	0.47	-	-	-	-	-	-	-
FISH	0006	0.31	-	-	-	-	-	-	-
1986	0005	0.28	-	-	-	-	-	-	-
	0001	0.39	-	-	-	-	-	-	-
	0007	0.41	-	-	-	-	-	-	-
	1511	0.24	-	<0.02	<0.2	1.5	-	1.1	11.
	1502	0.20	-	<0.02	<0.2	1.1	-	1.3	12.
	1513	0.17	-	<0.02	<0.2	2.9	-	0.19	7.3
	1505	0.23	-	<0.02	<0.2	0.83	-	0.69	6.8
1987	1501	0.16	-	<0.02	<0.2	1.4	-	0.70	7.2
	1504	0.39	-	<0.02	0.35	1.6	-	1.5	7.0
	1514	0.16	-	<0.02	<0.2	1.3	-	1.7	8.0
	1503	0.15	-	<0.02	0.47	1.6	-	0.53	8.9
	1509	0.16	-	<0.02	<0.2	3.3	-	0.48	9.4

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TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	1506	0.16	-	<0.02	<0.2	0.93	-	0.99	8.3
	1507	0.14	-	<0.02	<0.2	2.5	-	0.31	8.1
	1510	0.12	-	<0.02	<0.2	0.98	-	1.4	9.4
	1512	0.18	-	<0.02	<0.2	1.3	-	0.45	7.0
	1508	0.18	-	<0.02	<0.2	1.5	-	0.23	9.2
	1500	0.11	-	<0.02	<0.2	0.62	-	0.88	5.6
	0011	0.11	-	<0.02	<0.2	0.75	<0.05	0.30	6.3
	0000	0.19	-	<0.02	<0.2	1.1	<0.05	0.62	10.
	0003	0.09	-	<0.02	<0.2	0.91	0.06	0.50	5.8
	0006	0.14	-	<0.02	<0.2	0.69	<0.05	0.30	6.8
	0008	0.14	-	<0.02	<0.2	0.65	<0.05	0.36	9.3
	0014	0.19	-	<0.02	<0.2	0.87	<0.05	0.19	6.6
1988	0012	0.19	-	<0.02	<0.2	0.62	<0.05	0.58	6.3
	0013	0.19	-	<0.02	<0.2	0.73	<0.05	0.57	6.3
	0009	0.12	-	0.02	<0.2	0.52	<0.05	0.66	6.8
	0010	0.17	-	<0.02	<0.2	0.58	<0.05	1.5	10.
	0002	0.10	-	<0.02	<0.2	1.8	<0.05	0.72	6.3
	0004	0.26	-	<0.02	<0.2	1.0	<0.05	0.29	4.1
	0001	0.13	-	<0.02	<0.2	0.93	0.05	0.54	6.2
	0005	0.13	-	<0.02	<0.2	0.72	<0.05	0.26	5.2
	0007	0.15	-	<0.02	<0.2	0.56	<0.05	0.20	5.9
	Mountain whitefish								
	0018	0.10	0.11	0.05	<0.2	0.39	-	<0.1	3.3
	0608	0.14	0.16	0.03	0.27	2.5	-	0.29	37.
	0604	<0.05	0.04	<0.02	<0.2	0.53	-	<0.1	6.6
	0603	0.18	0.16	0.02	<0.2	0.63	-	<0.1	5.7
	0600	0.12	0.09	<0.02	<0.2	0.52	-	<0.1	6.4
1986	0602	0.10	0.11	<0.02	<0.2	0.96	-	<0.1	5.5
	0020	0.14	0.13	0.04	<0.2	0.55	-	0.11	6.0
	0019	0.10	0.10	0.02	<0.2	0.41	-	<0.1	7.2
	0601	0.10	0.10	0.03	<0.2	0.89	-	0.14	5.1
	0609	0.09	0.08	<0.02	<0.2	0.76	-	<0.1	3.8
	0606	0.06	0.06	<0.02	<0.2	0.52	-	<0.1	5.3

APPENDIX 2-1

TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	0605	0.18	0.16	<0.02	<0.2	0.49	-	<0.1	5.9
	0607	0.11	0.13	<0.02	<0.2	1.3	-	0.12	6.4
	0656	0.15	0.15	0.03	<0.2	0.47	-	<0.1	6.0
	6843	<0.05	-	0.04	<0.2	0.85	-	0.10	8.3
	6845	0.21	-	<0.02	<0.2	1.0	-	<0.1	7.0
	6846	0.12	-	0.02	<0.2	0.73	-	0.11	5.2
	6827	0.22	-	0.03	0.23	0.58	-	0.12	4.6
	6840	<0.05	-	<0.02	<0.2	0.62	-	<0.1	6.1
	6828	0.07	-	0.02	<0.2	0.70	-	<0.1	4.2
1987	6832	0.19	-	<0.02	<0.2	0.72	-	0.18	6.5
	6838	0.13	-	<0.02	<0.2	0.58	-	<0.1	5.3
	6830	0.20	-	0.02	<0.2	1.02	-	0.15	4.6
	6844	0.05	-	<0.02	<0.2	0.65	-	<0.1	7.2
	6834	0.13	-	<0.02	<0.2	0.87	-	0.15	5.3
	6831	0.20	-	<0.02	<0.2	0.89	-	<0.1	5.8
	6829	0.19	-	<0.02	<0.2	0.53	-	0.11	4.4
	6833	0.19	-	<0.02	0.36	1.3	-	0.11	5.7
	6841	<0.05	-	<0.02	<0.2	0.69	-	<0.1	5.7
	0017	0.19	-	0.04	<0.2	0.54	<0.05	<0.1	3.7
	0018	0.14	-	0.02	<0.2	0.79	<0.05	<0.1	3.9
	0019	0.10	-	<0.02	<0.2	0.82	0.06	<0.1	4.2
	0026	0.12	-	<0.02	<0.2	0.96	<0.05	<0.1	4.5
	0031	0.16	-	0.03	<0.2	0.54	<0.05	0.15	3.9
	0023	0.15	-	0.05	<0.2	0.37	0.05	0.17	5.3
1988	0034	0.09	-	<0.02	<0.2	0.54	<0.05	<0.1	3.5
	0028	0.16	-	<0.02	<0.2	0.84	0.06	0.11	4.4
	0025	0.12	-	0.02	<0.2	0.63	<0.05	<0.1	4.0
	0029	0.09	-	0 02	<0.2	0.89	<0.05	<0.1	5.8
	0033	0.18	-	0.05	<0.2	0.51	0.14	0.11	5.6
	0030	0.22	-	0.02	<0.2	0.83	0.06	0.14	5.6
	0027	0.10	-	0.02	<0.2	0.98	<0.05	<0.1	5.4
	0032	0.10	-	-	<0.2	0.66	<0.05	<0.1	4.5
	0024	0.17	-	0.02	<0.2	0.67	0.06	0.13	4.4

APPENDIX 2-1

TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	Rainbow trout								
	6847	0.05	-	<0.02	<0.2	0.59	-	<0.1	6.9
	6849	0.05	-	<0.02	<0.2	2.0	-	<0.1	6.7
	6837	<0.05	-	<0.02	<0.2	0.93	-	<0.1	6.4
1987	6848	0.05	-	<0.02	<0.2	1.6	-	<0.1	5.9
	6836	0.06	-	<0.02	0.28	0.90	-	<0.1	5.5
	6835	0.05	-	<0.02	<0.2	1.9	-	<0.1	6.2
	6826	<0.05	-	<0.02	<0.2	0.66	-	<0.1	7.3
	0015	0.09	-	<0.02	<0.2	0.76	<0.05	<0.1	3.5
	0022	0.07	-	<0.02	<0.2	0.82	<0.05	<0.1	4.2
	0016	0.08	-	<0.02	<0.2	0.51	<0.05	<0.1	3.2
	Sturgeon								
1986	-	0.16	-	-	-	-	-	-	-
1987	-	0.69	-	-	-	-	-	-	-
	Walleye								
	0003	0.20	0.20	<0.02	<0.2	0.40	-	<0.1	4.8
	0004	0.21	0.25	<0.02	<0.2	0.41	-	<0.1	6.2
	0006	0.55	0.60	<0.02	<0.2	<0.2	-	<0.1	3.8
	0000	0.76	0.71	<0.02	<0.2	0.35	-	<0.1	4.6
	0005	0.50	0.41	<0.02	<0.2	0.22	-	<0.1	5.5
1986	0009	0.40	0.34	<0.02	<0.2	0.21	-	<0.1	4.8
	0001	0.31	0.30	<0.02	<0.2	0.28	-	<0.1	5.2
	0007	0.27	0.27	<0.02	<0.2	0.24	-	<0.1	3.9
	0008	0.34	0.33	<0.02	<0.2	<0.2	-	<0.1	4.1
	0010	0.20	0.23	<0.02	<0.2	0.25	-	<0.1	4.0
	0002	0.21	0.26	<0.02	<0.2	0.29	-	<0.1	4.0
	0001	0.24	-	-	-	-	-	-	-
	0002	0.54	-	-	-	-	-	-	-
	6839	0.34	-	<0.02	<0.2	0.47	-	<0.1	6.0
1987	6842	0.25	-	<0.02	<0.2	0.39	-	<0.1	5.0
	6635	0.21	-	<0.02	<0.2	0.43	-	<0.1	5.7
	6638	0.07	-	<0.02	<0.2	0.32	-	<0.1	6.4

APPENDIX 2-1

TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	6633	0.33	-	<0.02	<0.2	0.47	-	<0.1	5.4
	6639	0.26	-	<0.02	<0.2	0.42	-	<0.1	4.8
	6631	0.36	-	<0.02	<0.2	1.7	-	<0.1	5.7
	6626	0.29	-	<0.02	<0.2	0.97	-	<0.1	5.4
	6629	0.32	-	<0.02	<0.2	0.65	-	<0.1	6.3
	6627	0.27	-	<0.02	0.36	1.2	-	<0.1	5.2
	6628	0.31	-	<0.02	0.32	0.58	-	<0.1	4.7
	6632	0.14	-	<0.02	<0.2	0.23	-	<0.1	5.0
	6636	0.23	-	<0.02	<0.2	0.46	-	<0.1	6.3
	6634	0.38	-	<0.02	<0.2	0.40	-	<0.1	6.3
	6630	0.17	-	<0.02	<0.2	0.41	-	<0.1	5.2
	6637	0.17	-	<0.02	<0.2	0.34	-	<0.1	5.1
	-	0.37	-	-	-	-	-	-	-
1987	-	0.29	-	-	-	-	-	-	-
	-	0.29	-	-	-	-	-	-	-
	-	0.19	-	-	-	-	-	-	-
	-	0.44	-	-	-	-	-	-	-
	-	0.42	-	-	-	-	-	-	-
	-	0.39	-	-	-	-	-	-	-
	-	0.39	-	-	-	-	-	-	-
	-	0.21	-	-	-	-	-	-	-
	-	0.38	-	-	-	-	-	-	-
	-	0.31	-	-	-	-	-	-	-
	-	0.21	-	-	-	-	-	-	-
	-	0.22	-	-	-	-	-	-	-
	-	0.44	-	-	-	-	-	-	-
	-	0.61	-	-	-	-	-	-	-
	-	0.30	-	-	-	-	-	-	-
	-	1.02	-	-	-	-	-	-	-
	-	0.35	-	-	-	-	-	-	-
	-	0.47	-	-	-	-	-	-	-
	-	0.26	-	-	-	-	-	-	-
	-	0.33	-	-	-	-	-	-	-
1988	0021	0.61	-	<0.02	<0.2	0.62	<0.05	<0.1	5.3

APPENDIX 2-1

TABLE 2

Concentrations of Metals (ug/g Wet Weight) in Muscle Tissue of Fish Taken from the Columbia River from 1986 to 1988

DATE	SAMPLE NO.	Hg PROV. LAB	Hg FEDERAL LAB	Cd	Cr	Cu	Ni	Pb	Zn
	0020	0.41	-	<0.02	<0.2	0.45	<0.05	<0.1	4.1
	0047	0.37	-	<0.02	<0.2	0.45	<0.05	<0.1	5.4
	0038	0.27	-	<0.02	<0.2	0.30	<0.05	<0.1	3.5
	0039	0.68	-	<0.02	<0.2	<0.2	<0.05	<0.1	5.9
	0042	0.31	-	<0.02	<0.2	0.47	<0.05	<0.1	5.0
	0036	0.31	-	<0.02	<0.2	0.46	<0.05	<0.1	3.9
1988	0040	0.39	-	<0.02	<0.2	0.31	<0.05	<0.1	4.0
	0041	0.24	-	<0.02	<0.2	0.33	<0.05	<0.1	5.3
	0043	0.20	-	<0.02	<0.2	0.50	<0.05	0.42	5.1
	0045	0.16	-	<0.02	<0.2	0.44	<0.05	<0.1	4.3
	0044	0.32	-	<0.02	<0.2	0.54	0.05	<0.1	5.7
	0037	0.28	-	<0.02	<0.2	0.39	<0.05	<0.1	4.6
	0046	0.25	-	<0.02	<0.2	0.34	<0.05	<0.1	4.6
	0035	0.42	-	<0.02	<0.2	0.63	<0.05	<0.1	5.5

APPENDIX 3-2

RESULTS OF ANALYSES OF VARIANCE/COVARIANCE COMPARING ANNUAL DIFFERENCES IN MERCURY LEVELS IN FISH COLLECTED FROM THE COLUMBIA RIVER, 1980 TO 1988

(Pages 1 to 4)

APPENDIX 3-2

Results of Analyses of Variance/Covariance on Mercury in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.0211	0.0053	2.2867
Error	74	0.1707	0.0023	-
Total	78	0.1919	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0115	0.0115	5.261
Error	73	0.1593	0.0022	-
Equal Slopes	4	0.0068	0.0017	0.7727
Error	69	0.1524	0.0022	-
Adj. Group Means	4	0.0139	0.0035	1.588
Error	73	0.1593	0.0022	-
Total	77	0.1731	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	7.200
df	4	4

APPENDIX 3-2

Results of Analyses of Variance/Covariance on Mercury in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	0.0556	0.0111	3.2052
Error	91	0.3155	0.0035	-
Total	96	0.3711	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.1561	0.1561	88.136
Error	90	0.1594	0.0018	-
Equal Slopes	5	0.0134	0.0027	1.5647
Error	85	0.1460	0.0017	-
Adj. Group Means	5	0.0180	0.0036	2.029
Error	90	0.1594	0.0018	-
Total	95	0.1774	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	35.378	9.125
df	5	5

APPENDIX 3-2

Results of Analyses of Variance/Covariance on Mercury in Walleye, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.0573	0.0143	0.6516
Error	74	1.6275	0.0220	-
Total	78	1.6848	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.1171	0.1171	5.658
Error	73	1.5104	0.0207	-
Equal Slopes	4	0.1495	0.0374	1.8944
Error	69	1.3610	0.0197	-
Adj. Group Means	4	0.0312	0.0078	0.377
Error	73	1.5104	0.0207	-
Total	77	1.5416	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	9.024	6.000
df	4	4

APPENDIX 3-2

Results of Analyses of Variance/Covariance on Mercury in Rainbow Trout, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.0046	0.0023	5.8707
Error	22	0.0087	0.0004	-
Total	24	0.0133	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0031	0.0031	11.683
Error	21	0.0056	0.0003	-
Equal Slopes	2	0.0003	0.0001	0.4696
Error	19	0.0053	0.0003	-
Adj. Group Means	2	0.0011	0.0006	2.107
Error	21	0.0056	0.0003	-
Total	23	0.0067	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	2.996	2.869
df	2	2

APPENDIX 3-3

RESULTS OF ANALYSES OF VARIANCE/COVARIANCE COMPARING ANNUAL DIFFERENCES IN CADMIUM, CHROMIUM, COPPER, LEAD AND ZINC LEVELS IN FISH COLLECTED FROM THE COLUMBIA RIVER, 1980 TO 1988

(Pages 1 to 30)

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Cadmium in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.0057	0.0014	7.537
Error	74	0.0140	0.0002	-
Total	78	0.0197	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0002	0.0002	0.844
Error	73	0.0138	0.0002	-
Equal Slopes	4	0.0004	0.0001	0.457
Error	69	0.0135	0.0002	-
Adj. Group Means	4	0.0058	0.0015	7.723
Error	73	0.0138	0.0002	-
Total	77	0.0197	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	565.345
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Cadmium in Largescale Suckers, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.0001	0.0000	1.8958
Error	43	0.0006	0.0000	-
Total	45	0.0006	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0000	0.0000	0.000
Error	42	0.0006	0.0000	-
Equal Slopes	2	0.0000	0.0000	0.0237
Error	40	0.0006	0.0000	-
Adj. Group Means	2	0.0000	0.0000	1.719
Error	42	0.0006	0.0000	-
Total	44	0.0006	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	5.586	451.190
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Cadmium in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	0.0016	0.0003	1.2982
Error	83	0.0198	0.0002	-
Total	88	0.0214	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0004	0.0004	1.847
Error	82	0.0194	0.0002	-
Equal Slopes	5	0.0019	0.0004	1.6497
Error	77	0.0175	0.0002	-
Adj. Group Means	5	0.0018	0.0004	1.536
Error	82	0.0194	0.0002	-
Total	87	0.0212	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	27.734	17.468
df	5	5

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Cadmium in Mountain Whitefish, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	3	0.0006	0.0002	0.7203
Error	53	0.0141	0.0003	-
Total	56	0.0146	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0006	0.0006	2.155
Error	52	0.0135	0.0003	-
Equal Slopes	3	0.0012	0.0004	1.6040
Error	49	0.0123	0.0003	-
Adj. Group Means	3	0.0009	0.0003	1.123
Error	52	0.0135	0.0003	-
Total	55	0.0144	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	24.528	14.578
df	3	3

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Chromium in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.7875	0.1969	5.388
Error	74	2.7042	0.0365	-
Total	78	3.4917	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0003	0.0003	0.008
Error	73	2.7039	0.0370	-
Equal Slopes	4	0.0481	0.0120	0.312
Error	69	2.6558	0.0385	-
Adj. Group Means	4	0.7737	0.1934	5.222
Error	73	2.7039	0.0370	-
Total	77	3.4776	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	ERR
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Chromium in Largescale Suckers, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.0173	0.0086	2.1367
Error	43	0.1738	0.0040	-
Total	45	0.1910	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0018	0.0018	0.437
Error	42	0.1720	0.0041	-
Equal Slopes	2	0.0120	0.0060	1.5025
Error	40	0.1600	0.0040	-
Adj. Group Means	2	0.0124	0.0062	1.513
Error	42	0.1720	0.0041	-
Total	44	0.1844	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	5.586	ERR
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Chromium in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	34.5424	6.9085	7.3170
Error	82	77.4221	0.9442	-
Total	87	111.9646	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0963	0.0963	0.101
Error	81	77.3258	0.9546	-
Equal Slopes	5	0.9419	0.1884	0.1874
Error	76	76.3839	1.0051	-
Adj. Group Means	5	34.1013	6.8203	7.144
Error	81	77.3258	0.9546	-
Total	86	111.4271	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	27.367	ERR
df	5	5

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Chromium in Mountain Whitefish, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	3	0.0066	0.0022	1.1312
Error	52	0.1012	0.0019	-
Total	55	0.1078	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0001	0.0001	0.040
Error	51	0.1011	0.0020	-
Equal Slopes	3	0.0020	0.0007	0.3267
Error	48	0.0991	0.0021	-
Adj. Group Means	3	0.0062	0.0021	1.038
Error	51	0.1011	0.0020	-
Total	54	0.1073	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	24.310	ERR
df	3	3

APPENDIX 3-3

Results in Analyses of Variance/Covariance on Chromium in Walleye, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.3396	0.0849	16.8177
Error	53	0.2676	0.0050	-
Total	57	0.6072	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0103	0.0103	2.073
Error	52	0.2573	0.0049	-
Equal Slopes	4	0.1212	0.0303	10.6804
Error	48	0.1361	0.0028	-
Adj. Group Means	4	0.3498	0.0875	17.674
Error	52	0.2573	0.0049	-
Total	56	0.6071	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	9.077	ERR
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Chromium in Walleye, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.0089	0.0045	1.7109
Error	39	0.1016	0.0026	-
Total	41	0.1105	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0008	0.0008	0.297
Error	38	0.1008	0.0027	-
Equal Slopes	2	0.0036	0.0018	0.6619
Error	36	0.0972	0.0027	-
Adj. Group Means	2	0.0079	0.0040	1.491
Error	38	0.1008	0.0027	-
Total	40	0.1087	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	4.335	ERR

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	5.6972	1.4243	9.591
Error	74	10.9894	0.1485	-
Total	78	16.6866	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0573	0.0573	0.383
Error	73	10.9320	0.1498	-
Equal Slopes	4	0.8855	0.2214	1.520
Error	69	10.0466	0.1456	-
Adj. Group Means	4	5.2581	1.3145	8.778
Error	73	10.932	0.1498	-
Total	77	16.1902	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	14.798
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Largescale Suckers, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	5.6157	2.8078	24.626
Error	43	4.9028	0.1140	-
Total	45	10.5184	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0280	0.0280	0.241
Error	42	4.8747	0.1161	-
Equal Slopes	2	0.7171	0.3586	3.450
Error	40	4.1576	0.1039	-
Adj. Group Means	2	5.2803	2.6401	22.747
Error	42	4.8747	0.1161	-
Total	44	10.1550	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	5.586	8.792
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	4.9990	0.9998	8.2176
Error	82	9.9766	0.1217	-
Total	87	14.9756	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0915	0.0915	0.750
Error	81	9.8851	0.1220	-
Equal Slopes	5	0.3414	0.0683	0.5437
Error	76	9.5438	0.1256	-
Adj. Group Means	5	4.9080	0.9816	8.043
Error	81	9.8851	0.1220	-
Total	86	14.7932	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	27.367	9.735
df	5	5

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Mountain Whitefish, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	3	2.4900	0.8300	6.3501
Error	52	6.7968	0.1307	-
Total	55	9.2867	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0078	0.0078	0.059
Error	51	6.7889	0.1331	-
Equal Slopes	3	0.1585	0.0528	0.3825
Error	48	6.6304	0.1381	-
Adj. Group Means	3	2.0055	0.6685	5.022
Error	51	6.7889	0.1331	-
Total	54	8.7944	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	24.310	8.582
df	3	3

APPENDIX 3-3
Results of Analyses of Variance/Covariance on Copper in Walleye, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	9.8432	2.4608	10.5378
Error	53	12.3767	0.2335	-
Total	57	22.2200	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.1350	0.1350	0.573
Error	52	12.2418	0.2354	-
Equal Slopes	4	0.6269	0.1567	0.6477
Error	48	11.6148	0.2420	-
Adj. Group Means	4	9.9756	2.4939	10.593
Error	52	12.2418	0.2354	-
Total	56	22.2174	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	9.077	2.578
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Walleye, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	3.9017	1.9508	8.4422
Error	39	9.0122	0.2311	-
Total	41	12.9139	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0765	0.0765	0.325
Error	38	8.9357	0.2351	-
Equal Slopes	2	0.6245	0.3123	1.3525
Error	36	8.3112	0.2309	-
Adj. Group Means	2	3.4076	1.7038	7.246
Error	38	8.9357	0.2351	-
Total	40	12.3433	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	4.335	0.301
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Copper in Rainbow Trout, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	2.1233	1.0617	7.5999
Error	22	3.0732	0.1397	-
Total	24	5.1965	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0384	0.0384	0.266
Error	21	3.0348	0.1445	-
Equal Slopes	2	0.3038	0.1519	1.0589
Error	19	2.7309	0.1437	-
Adj. Group Means	2	1.9618	0.9809	6.787
Error	21	3.0348	0.1445	-
Total	23	4.9965	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	2.996	1.824
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Lead in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	2.1568	0.5392	3.204
Error	74	12.4538	0.1683	-
Total	78	14.6106	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.4624	0.4624	2.815
Error	73	11.9914	0.1643	-
Equal Slopes	4	0.6204	0.1551	0.941
Error	69	11.3711	0.1648	-
Adj. Group Means	4	1.5520	0.3880	2.362
Error	73	11.9914	0.1643	-
Total	77	13.5434	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	3.532
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Lead in Largescale Suckers, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.8367	0.4183	2.4702
Error	43	7.2821	0.1694	-
Total	45	8.1187	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0067	0.0067	0.039
Error	42	7.2754	0.1732	-
Equal Slopes	2	0.1360	0.0680	0.3810
Error	40	7.1394	0.1785	-
Adj. Group Means	2	0.8088	0.4044	2.334
Error	42	7.2754	0.1732	-
Total	44	8.0841	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	5.586	1.933
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Lead in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	0.0192	0.0038	0.4890
Error	83	0.6507	0.0078	-
Total	88	0.6699	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0254	0.0254	3.330
Error	82	0.6253	0.0076	-
Equal Slopes	5	0.0433	0.0087	1.1463
Error	77	0.5820	0.0076	-
Adj. Group Means	5	0.0328	0.0066	0.861
Error	82	0.6253	0.0076	-
Total	87	0.6581	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	27.734	25.410
df	5	5

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Lead in Mountain Whitefish, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	3	0.0053	0.0018	0.4549
Error	53	0.2057	0.0039	-
Total	56	0.2110	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0146	0.0146	3.972
Error	52	0.1911	0.0037	-
Equal Slopes	3	0.0090	0.0030	0.8077
Error	49	0.1821	0.0037	-
Adj. Group Means	3	0.0150	0.0050	1.363
Error	52	0.1911	0.0037	-
Total	55	0.2062	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	24.528	7.776
df	3	3

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Lead in Walleye, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	0.0152	0.0038	1.5141
Error	53	0.1327	0.0025	-
Total	57	0.1478	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0006	0.0006	0.224
Error	52	0.1321	0.0025	-
Equal Slopes	4	0.0029	0.0007	0.2731
Error	48	0.1292	0.0027	-
Adj. Group Means	4	0.0157	0.0039	1.542
Error	52	0.1321	0.0025	-
Total	56	0.1478	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	9.077	ERR
df	4	4

APPENDIX 3-3
Results of Analyses of Variance/Covariance on Lead in Walleye, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.0059	0.0029	0.8954
Error	39	0.1278	0.0033	-
Total	41	0.1336	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0005	0.0005	0.158
Error	38	0.1272	0.0033	-
Equal Slopes	2	0.0005	0.0003	0.0771
Error	36	0.1267	0.0035	-
Adj. Group Means	2	0.0062	0.0031	0.921
Error	38	0.1272	0.0033	-
Total	40	0.1334	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	4.335	ERR
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Largescale Suckers, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	34.7337	8.6834	1.917
Error	74	335.2441	4.5303	-
Total	78	369.9778	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.0450	0.0450	0.010
Error	73	335.1991	4.5918	-
Equal Slopes	4	38.6201	9.6650	2.246
Error	69	296.5790	4.2982	-
Adj. Group Means	4	34.7762	8.6940	1.893
Error	73	335.1991	4.5918	-
Total	77	369.9753	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	11.412	4.221
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Largescale Suckers, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	32.6047	16.3024	5.0409
Error	43	139.0633	3.2340	-
Total	45	171.6680	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	2.1610	2.1610	0.663
Error	42	136.9022	3.2596	-
Equal Slopes	2	4.8386	2.4193	0.7328
Error	40	132.0637	3.3016	-
Adj. Group Means	2	33.3528	16.6764	5.116
Error	42	136.9022	3.2596	-
Total	44	170.2551	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	5.586	0.163
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Mountain Whitefish, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	5	1.2367	0.2473	3.2489
Error	83	6.3188	0.0761	-
Total	88	7.5555	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.6077	0.6077	8.725
Error	82	5.7112	0.0696	-
Equal Slopes	5	0.2224	0.0445	0.6239
Error	77	5.4888	0.0713	-
Adj. Group Means	5	1.2149	0.2430	3.489
Error	82	5.7112	0.0696	-
Total	87	6.9261	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	27.734	40.454
df	5	5

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Mountain Whitefish, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	3	0.8439	0.2813	2.7256
Error	53	5.4697	0.1032	-
Total	56	6.3136	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.6049	0.6049	6.466
Error	52	4.8648	0.0936	-
Equal Slopes	3	0.1773	0.0591	0.6178
Error	49	4.6875	0.0957	-
Adj. Group Means	3	0.8363	0.2788	2.980
Error	52	4.8648	0.0936	-
Total	55	5.7011	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	24.528	26.900
df	3	3

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Walleye, 1980 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	4	6.9401	1.7350	3.6185
Error	53	25.4127	0.4795	-
Total	57	32.3528	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	1.7562	1.7562	3.860
Error	52	23.6565	0.4549	-
Equal Slopes	4	1.2594	0.3148	0.6747
Error	48	22.3971	0.4666	-
Adj. Group Means	4	8.6570	2.1643	4.757
Error	52	23.6565	0.4549	-
Total	56	32.3135	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	9.077	4.829
df	4	4

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Walleye, 1986 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	6.4981	3.2491	6.9353
Error	39	18.2709	0.4685	-
Total	41	24.7690	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.2174	0.2174	0.458
Error	38	18.0535	0.4751	-
Equal Slopes	2	0.5135	0.2567	0.5270
Error	36	17.5400	0.4872	-
Adj. Group Means	2	4.9867	2.4933	5.248
Error	38	18.0535	0.4751	-
Total	40	23.0401	-	-

Bartlett's Test:

	X	Y
Adj. Chi Square	4.335	1.088
df	2	2

APPENDIX 3-3

Results of Analyses of Variance/Covariance on Zinc in Rainbow Trout, 1983 to 1988

Unadjusted ANOVA:

SOURCE	df	SS	MS	F
Treatment	2	0.7798	0.3899	7.5554
Error	22	1.1354	0.0516	-
Total	24	1.9152	-	-

ANCOVA Table:

SOURCE	df	SS	MS	F
Pooled Regression	1	0.2744	0.2744	6.694
Error	21	0.8609	0.0410	-
Equal Slopes	2	0.0634	0.0317	0.7552
Error	19	0.7975	0.0420	-
Adj. Group Means	2	0.4538	0.2269	5.534
Error	21	0.8609	0.0410	-
Total	23	1.3147	-	

Bartlett's Test:

	X	Y
Adj. Chi Square	2.996	6.359
df	2	2